SOLICITATION NO. NNC10341434Q

SPECIFICATION FOR SPUR TEST GEARS:

1. **Quantity of parts** – the vendor shall deliver 110 test gears meeting this specification and meeting the requirements of NASA GRC drawing CD851944–004–Rev. A.

2. **Material**
   2.1. The test gears shall be made from steel alloy meeting Aerospace Material Specification (AMS) 6308D
   2.2. The vendor shall make the gears using forged bars provided by NASA. NASA has acquired two forged bars of material. The size of each bar is 4 inches diameter and 60 inches long. The two bars will be delivered by NASA to the vendor for purposes of making the gears. The bars were manufactured using a VIM-VAR process. The forging vendor provided NASA with the following material certification information.

AMS 6308D VIM-VAR material

Chemical Analysis Wt%:

Locn	C	Si	Mn	S	P	Cr	V	Ni	Mo	Cu
7T	.12	.83	.33	.001	.002	1.04	.11	2.03	3.35	2.08
7B	.12	.79	.37	.001	.003	1.02	.10	1.97	3.28	2.07

Microcleanliness per ASTM E45-05:

	A		B		C		D	
Locations:	t	h	t	h	t	h	t	h
7T	0	0	0	0	0	0	0	0
7B	0	0	0	0	0	0	0	0

The worst field and total rateable fields frequency requirements were found to be within applicable specification limits.

Macroetch per ASTM A-604-07: 1A, 2A, 3A, 4A

Grain Size per ASTM E-112-96: 5.5

Frequency Severity heat avg. per AMS 2300K: f/s = 0/0
This test was performed at Product Evaluation Systems, Inc.

   2.3. Any excess bar stock material not needed and used by the vendor for gear manufacture shall be returned to NASA. Excess bar stock, if any, shall be delivered together with the test gears.

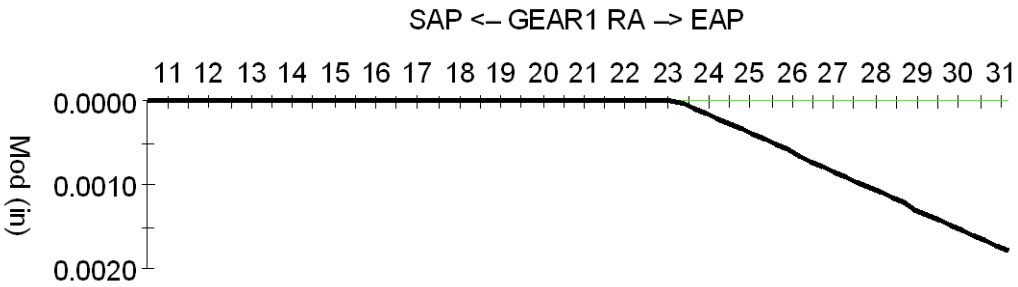
3. **Gear geometry**
   3.1. The gears shall be made per NASA drawing 851944–4 for "Pitting gears – high torque". The following numbered sections provide the details of the required part geometry.
   3.2. The gears shall have flanks and roots ground. There shall be a smooth transition of profile to root radius. A 0.005 inch max. undercut to 0.001 inch max. step is permissible at the blend of profile and root radius, undercut or step must be below the start of active profile (true involute form) that is to start at or below 10.2 degree of roll. Radius at step must comply with minimum fillet radius.

3.3. The gear tooth profile shall include involute modification. The nominal desired profile shall be as defined in chart 3.3 below. The final involute profile shall be a smooth curve. After final grinding the tooth profile shall meet the nominal desired profile to within tolerance for AGMA class 13, or better, as defined by AGMA 2002-A88, "Gear Classification and Inspection Handbook"

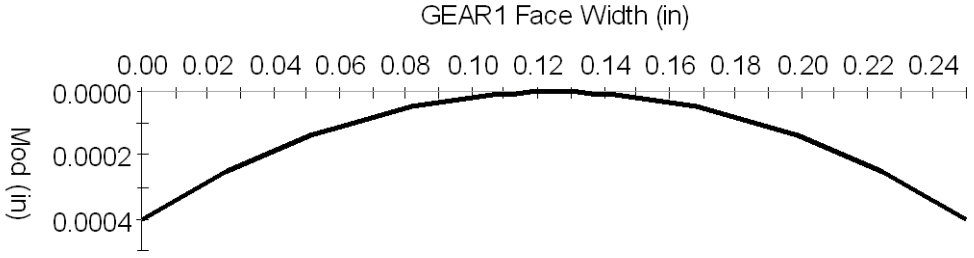
Chart 3.3 – Involute profile modification data and plot

SAP (deg)	10.506
LPSTC (deg)	18.345
Oper Pitch (deg)	20.854
Theo Pitch (deg)	20.854
HPSTC (deg)	23.363
Tip (deg)	31.202

Nominal profile modification to be 0.0018 inch magnitude at tip, linear profile modification starting at 23.3 degree roll ending at 31.2 degree roll..



3.4. The gear tooth lead profile shall include a circular crown lead profile. The nominal desired lead profile shall be as defined in chart 3.4 below. After final grinding the tooth profile shall meet the nominal desired profile to within tolerance for AGMA class 13, or better, as defined by AGMA 2002-A88, "Gear Classification and Inspection Handbook". The lead profile shall be free of lead hollow to within 0.0001 inch max. local irregularity.



3.5. After final grinding, the gears shall meet AGMA Class 13 or better as defined by AGMA 2002-A88, "Gear Classification and Inspection Handbook" for index and tooth spacing errors.
3.6. The surface roughness on the active profiles of the ground gears shall be 14 microinch roughness R.M.S or better.

4. Heat treatment, hardness, and case requirements

4.1. The gears shall be case-carburized and heat treated to aerospace quality. Table 4.1 below provides a heat treatment cycle that is proposed. The process defined in Table 4.1 is based on NASA's experience with this gear geometry and AMS material specification. The manufacturer is responsible to meet final requirements for surface hardness, case depth, case properties, and core properties. NASA recognizes that the manufacturer might desire to deviate from the process based on manufacturing experience. The manufacturer may deviate from the guideline only with approval from NASA.

TABLE 4.1 —Required heat treatment process for AMS 6308B NASA test gears. A deviation from this heat treatment process requires approval from NASA. Application and removal of copper plating are also required processes but are not included in the table.

Table 4.1 – Heat Treatment Process for AMS6308B test gears

Pre-oxidize	1500 °F for 30 minutes air atmosphere
Gas Carburize	1700 °F target, [1625 – 1725] for 5 hours
Temper within 5 hours	1200-1315 °F for 4 hours minimum
Austentize / Harden	1700 °F target, [1650 – 1715 °F] for 30 minutes
Oil quench within 30 seconds	75-140 C
Subzero cool treatment	within 30 minutes, -110 °F or less, for 3 hours minimum
Double temper	450°F, 2 + 2 hours
Final grind	
Stress relief after final grind	450°F, 2 hours

4.2. The drawing includes a note for masking of surfaces from carburization. All surfaces except the gear teeth profiles and roots are to be masked. The masking shall be by copper plating.

4.3. Surface hardness. Parts shall be checked for hardness after the quenching operation and before the subzero cool operation. Parts shall have a minimum hardness of Rc 58 and maximum hardness of Rc 64, parts not meeting this requirement shall be rejected as unacceptable.

4.4. Case depth. The gears shall have a finished case depth of 0.040 inch minimum to 0.056 inch maximum. The case depth shall be verified by witness coupons of appropriate geometry or by using sectors of gears. If witness coupons are used

the vendor must account for the grinding stock. The case depth requirement is for the mid-height of the gear tooth, and it represents the depth to an equivalent hardness of HRC 50 as obtained by Vickers hardness check. Results of quality checks for case depth requirements (including consideration of final grinding stock) shall be provided.

4.5. Case microstructure - Witness coupons of appropriate geometry or sectors of gears shall be inspected to verify aircraft quality microstructure was produced by the heat treatment. The test samples shall be etched and examined for free carbides and retained austenite. Parts with heavy continuous carbide networks are not acceptable. Visual retained austenite (maximum amount) uniformly distributed is 10%, localized areas with a higher amount is acceptable so long as the overall average is less than 10%. The manufacturer shall provide results of the quality check procedures.

4.6. Gears shall be free of grinding burns per aircraft standards. All delivered gears shall be checked for grinding burns by nital etch inspection .

4.7. The gears shall be free of cracks. All delivered gears shall be checked for cracks using magnetic particle inspection. Indications on gear teeth shall meet the acceptance criteria of ANSI/AGMA 2001-C95 for grade 3 carburized gears.

5. **Parts marking.** Gears shall be provided serial numbers via permanent marking. The serial numbers shall follow the format “10-L53-XXX”. The serial number and any other permanent marking shall be on the side of the gear within the region falling between diameters 2.00 inch to 2.80 inch.

6. **Protection from corrosion and handling damage.** After final grind the gears shall be protected using good industry practice to maintain the gears free of dings, scratches, and corrosion. Gears delivered with corrosion or handling damage will not be accepted.

7. **Documentation of compliance.** Documents showing compliance with this specification shall be delivered with the gears as follows.

7.1. The vendor shall supply legible copies of quality control checks and measurements made to make certain the delivered gears meet the part geometry specified on the drawing.

7.2. The vendor shall supply a legible copy of certification and quality controls of the heat treatment process. Actual process steps, time, and temperatures used shall be documented. Copies of certification of case depth and surface hardness requirements shall be provided

7.3. The vendor shall supply legible copies of results of nital etch and magnetic particle inspection checks.

7.4. The vendor shall supply legible copies of results of check for surface roughness requirements for the active gear profile.

7.5. The vendor shall supply legible copies of gear tooth involute, lead, and tooth spacing inspections for each gear delivered. The inspection documents shall be labeled with the individual serial number as was provided on the gear per Section 5 above. The gear inspection chart shall indicate the AGMA quality number actually achieved as defined per ANSI/AGMA 2001-C95.